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Report On Correlation Between R-Value And k-Value As A Basis For Concrete Pavement Design

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John L. Beaton

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16. ABSTRACT

Synopsis:

The purpose of this investigation was to establish a relationship between R-value and k-value for various soils so that soil survey data normally available for a project could be used in the design of Portland cement concrete pavements.

Twenty k-values were established on going California highway contracts by the Portland Cement Association using their truck mounted plate bearing test equipment. Samples of these same soils were tested by the Materials and Research Department to determine R-values. Other tests were made by both agencies to define the type of soil at each test location.

The investigation showed that a precise correlation does not exist between R-value and k-value for the typical California soils tested. It does appear that a conservative relationship can be established which will be usable in developing an empirical modification of Portland cement concrete pavement design methods that use Westergarrd's k-value.

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Research Project
HPR-1(3)(4),D-5-20
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13-624130

State of California

Department of Public Works

Division of Highways

Design Department

September 23, 1966

REPORT ON CORRELATION BETWEEN R-VALUE AND k-VALUE AS A BASIS FOR CONCRETE PAVEMENT DESIGN

STUDY MADE BY — DESIGN DEPARTMENT

Under direction of — A. C. Estep
Supervision and report — Paul Wagner

FIELD WORK BY — PORTLAND CEMENT ASSOCIATION

Field supervision — Peter J. Nussbaum
State representative — Clyde Gates

LABORATORY WORK BY — MATERIALS AND RESEARCH

Under direction of — J. L. Beaton
Work supervision — Clyde Gates

SYNOPSIS

The purpose of this investigation was to establish a relationship between R-value and k-value for various soils so that soil survey data normally available for a project could be used in the design of portland cement concrete pavements.

Twenty k-values were established on going California highway contracts by the Portland Cement Association using their truck mounted plate bearing test equipment. Samples of these same soils were tested by the Materials and Research Department to determine R-values. Other tests were made by both agencies to define the type of soil at each test location.

The investigation showed that a precise correlation does not exist between R-value and k-value for the typical California soils tested. It does appear that a conservative relationship can be established which will be usable in developing an empirical modification of portland cement concrete pavement design methods that use Westergaard's k-value.

INTRODUCTION

Most recognized methods for the design of portland cement concrete pavements use Westergaard's modulus of subgrade reaction (k-value) as the estimate of the support provided by the basement soil, subbase and base.

The desire was to establish a relationship between k-value and R-value for various soils in order that soil survey data normally available for California highway projects could be used in the design of rigid pavements.

Such a relationship is shown in chart form in Figure 9 on page 36 of the "PCA Soil Primer", but it was believed that this chart was constructed by comparing k-value and R-value with CBR (California Bearing Ratio). An investigation to establish a direct relationship was considered desirable, and there was no literature available indicating that this had ever been done.

This investigation was sponsored by the Bureau of Public Roads as work program HPR-1(3)(4), Item D-5-20.

It was originally proposed to perform R-value tests on twenty soil samples of known k-value. The samples were to be supplied by the Portland Cement Association, but only four samples were received.

The following are the test results:

Sample	R-Value	k-Value
P.C.A.	10	75
Corps of Engr. A	14	76
Corps of Engr. B	12	129
Corps of Engr. C	13	164

Early in February 1966, Mr. C. E. Warnes, local special representative of the PCA, informed us that they could not furnish more samples and offered to bring out equipment and personnel from Illinois to perform plate bearing tests for determining k-values on certain projects in California.

On February 24, 1966, a joint meeting was held at the Materials and Research Department between representatives of the Design Department, Materials and Research Department and the Portland Cement Association. It was decided to select 20 sites on current construction projects in California. The Portland Cement Association would perform plate bearing tests at no cost to the State. A representative of the Materials and Research Department would witness the tests and take samples from each site for R-value tests. It was believed that this would furnish more reliable data than the original proposal.

PROCEDURES

The Portland Cement Association established k-values of basement soils at twenty locations listed in Table 1. The test sites were compacted embankments with a minimum height of six feet and all on going California highway contracts.

Standard ASTM Des: D 1196-64 procedure with static loading for highways was used with the preload modification used at the AASHO Test Track. The preload was sufficient to produce 0.01 inch deflection and was repeated four times. The Ames dials were then set with no load, and test loading procedure was commenced.

A summary of test data received from the Portland Cement Association is shown in Table 2, grain size accumulation curves are plotted on Figures 1 to 5 and plate bearing deflection data is presented in chart form on Figures 6 to 9.

The Materials and Research Department performed R-value tests on samples from each test site using test method No. Calif. 301-F. The clayey soil samples (Nos. 3, 5, 8, 15, 17 and 19) had

low R-values and high k-values. The high k-values were no doubt due to relatively low moisture content of the clay soils in the field. It is standard practice to correct the k-values of plastic soils for eventual saturation by factors developed from consolidometer tests. The method used was Corps of Engineers, Military Standard 621A, Method 104 with the modification in specimen size of 2 inches in diameter and 7/8 inch thick. The seating load was 1.5 pounds per square inch and the deformation load was 10 pounds per square inch. The k-values, corrected k-values, and R-values are shown in Table 3. R-values versus k-values are plotted on Figure 10 including the twenty tests performed in California and the four samples furnished originally by PCA. Also shown is a curve representing the PCA chart values and a tentative empirical curve.

CONCLUSIONS

The data plotted on Figure 10 shows that a precise correlation does not exist between R-value and k-value for the typical soils tested. It further shows that the PCA chart indicates k-values that are too high for R-values over 60 under California conditions.

Correction factors based on the laboratory consolidation tests did not lower the k-values of clayey soils to realistic values. Experience elsewhere has shown that k-values for clays are less than 100 when measured at moisture contents found in embankments under pavements.

The design of pavements, bases and subbases is not an exact science as there are too many variables and uncontrolled natural conditions to be correlated in exact mathematical terms. It appears that an R-value vs k-value curve can be drawn on the conservative side of the data obtained by this investigation and k-values obtained from this curve can be used in a series of trial designs. Such a tentative curve is shown by the dashed line on Figure 10. The curve can then be empirically adjusted so that the resulting designs conform to present key design criteria and California experience with the road life of portland cement concrete pavements.

It is believed that sufficient information has been gained from this study to enable us to proceed with the development of a design method for rigid pavements based on R-value data from preliminary soil surveys.

Table 1

k-Value - R-Value Study

Test Sites

Sample No.	Co. Rte. Sec.	Limits Mile Post	Contract No.	Sample Location
1	08-SBd-15	27.3/31.1	08-039644	C.L. Sta. 64+00 O.H. Line
2	08-Riv-62	0.4/7.2	08-029834	5' Rt. C.L. E. Roadway Sta. 94+15
3	08-Riv-71	7.7/13.4	08-074214	8' Rt. Sta. 843+25 E. Roadway
4	11-SD-395	18.2/23.4	11-037774	Sta. 1027+75 W. Roadway
5	11-SD-395	18.2/23.4	11-037774	Sta. 1021+50 W. Roadway
6	11-SD-395	18.2/23.4	11-037774	60' Lt. Sta. 1067+00
7	11-SD-5	53.7/R63.3	11-035724	Sta. 77+00 W. Roadway
8	07-Ven-101	22.5/26.2	07-033764	E. Bound on Ramp Sta. 382
9	07-Ven-101	22.5/26.2	07-033764	W. Bound on Ramp Sta. 304+75
10	07-LA-5	R65.5/R70.9	07-049314	15' Rt. Sta. 12+65
11	07-LA-5	R70.9/R74.5	07-049344	Sta. 204+00 W. Roadway
12	07-LA-5	R77.9/85.5	07-035104	Rte. 138 Connection
13	07-LA,Ker-5	85.0/89.4	07-035204	Lt. Sta. 675
14	06-Ker-5	14.8/38.8	06-037274	Sta. 462+50 W. Roadway
15	06-Fre-5	45.5/66.2	06-032814	Sta. 574 W. Roadway
16	03-Sac-80	R0.2/R1.6	03-100874	C.L. Sta. 90
17	03-Sac-99,80	2nd Ave. to A St.	03-039904	Off Ramp S. of Broadway
18	03-Sac-99,80	22.9/24.4, 2.5/3.3	03-039924	1000' S. of T. St.
19	03-Sac-5	29.8/34.6	03-061754	Sta. 499+10
20	03-Sac-5	24.4/25.8	14-061744	Frontage Road

Table 2

CALIFORNIA -- PLATE BEARING TESTS

Summary of Test Data

Site No	W wet pcf	W dry pcf	M.C. %	L L %	P L %	P I %	k pci
1	146	133	9.8			NP	240
2	135.5	130.5	3.8			NP	466
3	128	112.2	13.9	30	23	7	352
4	139.5	134.6	3.6			NP	334
5	128	112	14.2	32	22	10	387
6	137.5	129.5	6.1			NP	220
7	130	122.7	6.0			NP	223
8	122	108	12.9	32	22	10	300
9	132	122	8.3			NP	311
10	143	133	7.5			NP	420
11	125.5	114	10.0			NP	132
12	133.5	126.5	5.5			NP	328
13	137.5	126.4	8.8			NP	220
14	122.8	113.8	7.8			NP	285
15	131.5	115.2	14.2	27	18	9	346
16	125	116.8	7.0			NP	260
17	134.5	121.0	11.3	25	17	8	287
18	130.5	114.3	14.3			NP	317
19	132.5	114.2	16.2	32	18	14	319
20	127	121.9	4.2			NP	305

W wet = Wet Density

W dry = Dry Density

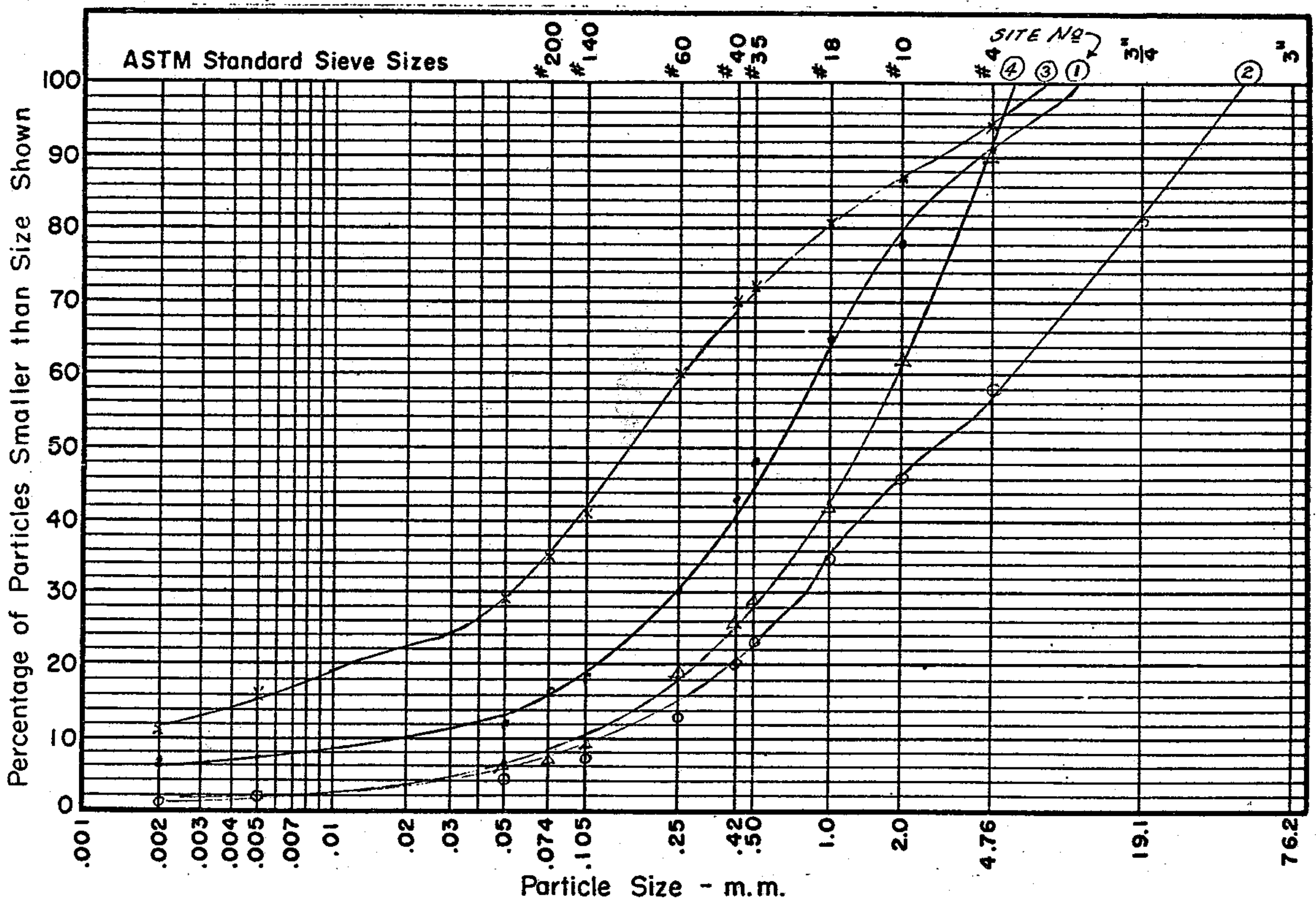
k = Modulus of Subgrade Reaction

Table 3

k-Value - R-Value Study

Test Results

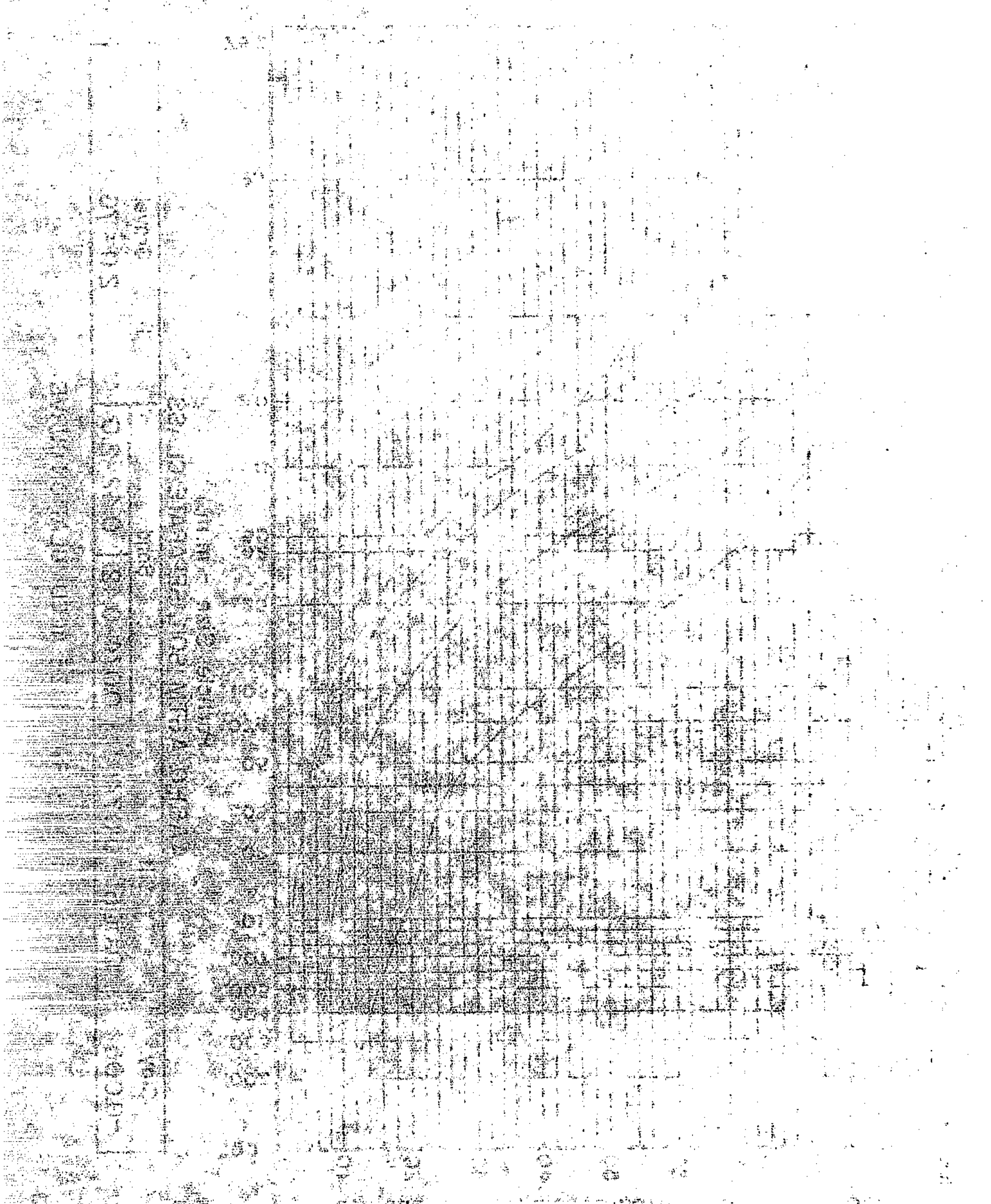
Site No.	Moisture Content %	LL %	PL %	PI %	k-Values Field Pci	k-Values Corrected Pci	M&R Test No.	R Value
1	9.8			NP	240		66-1511	73
2	3.8			NP	466		-1512	80
3	13.9	30	23	7	352	260	-1510	21
4	3.6			NP	334		-1639	80
5	14.2	32	22	10	387	268	-1640	12
6	6.1			NP	220		-1641	70
7	6.0			NP	223		-1565	47
8	12.9	32	22	10	300	91	-1566	13
9	8.3			NP	311		-1567	78
10	7.5			NP	420		-1568	32
11	10.0			NP	132		-1569	64
12	5.5			NP	328		-1632	67
13	8.8			NP	220		-1633	67
14	7.8			NP	285		-1634	70
15	14.2	27	18	9	346		-1635	20
16	7.0			NP	260		-1668	69
17	11.3	25	17	8	287	66	-1678	15
18	14.3			NP	317		-1688	56
19	16.2	32	18	14	319	235	-1690	17
20	4.2			NP	305		-1691	76

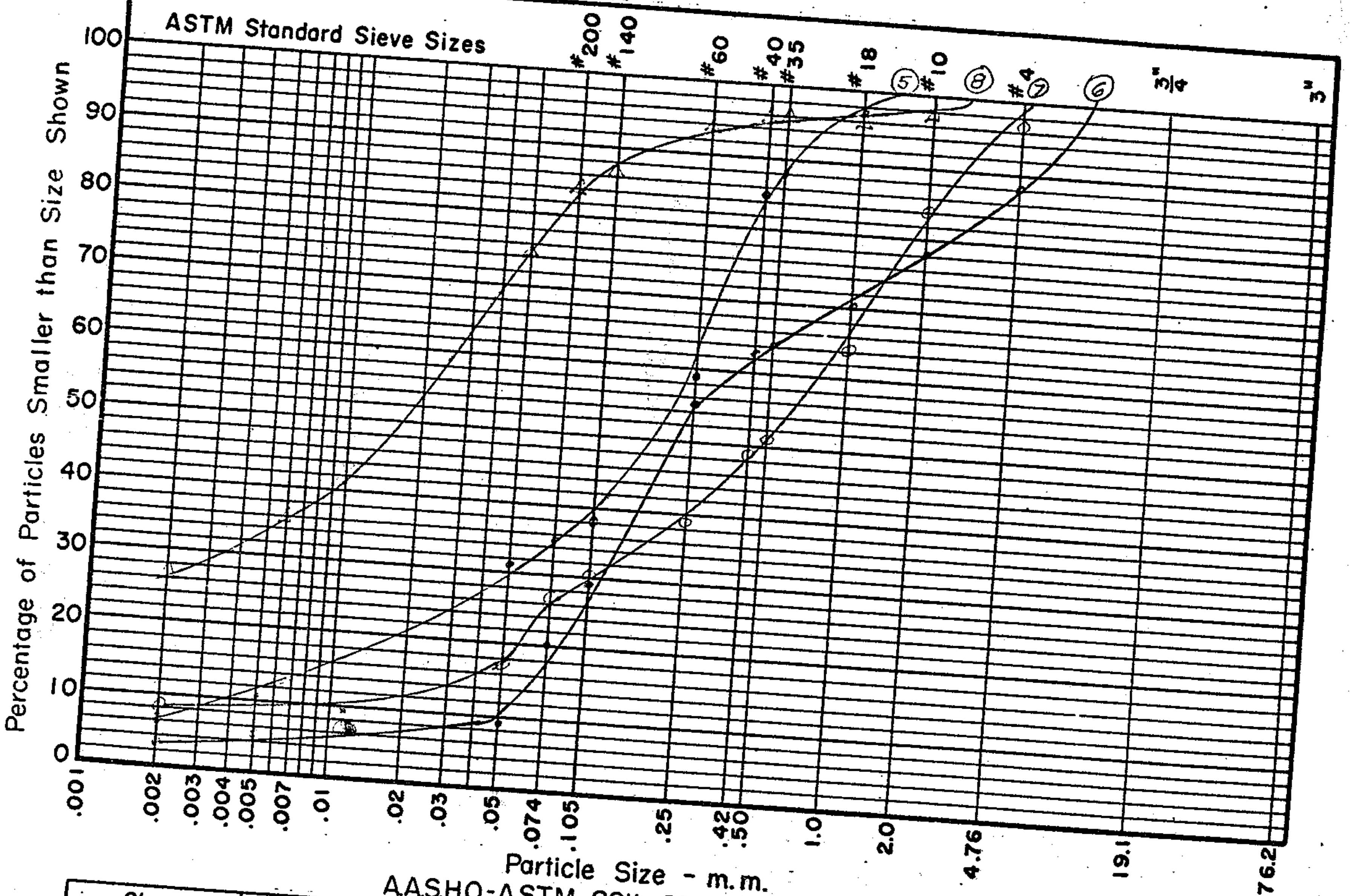


A.A.S.H.O.-A.S.T.M. SOIL SEPARATE CLASS

Clay	Silt	Sand		Gravel
-0.005	0.005 - 0.074	0.074-0.42	0.42-2.0	2.0 - 76.2

Fig. / -GRAIN SIZE ACCUMULATION CURVE

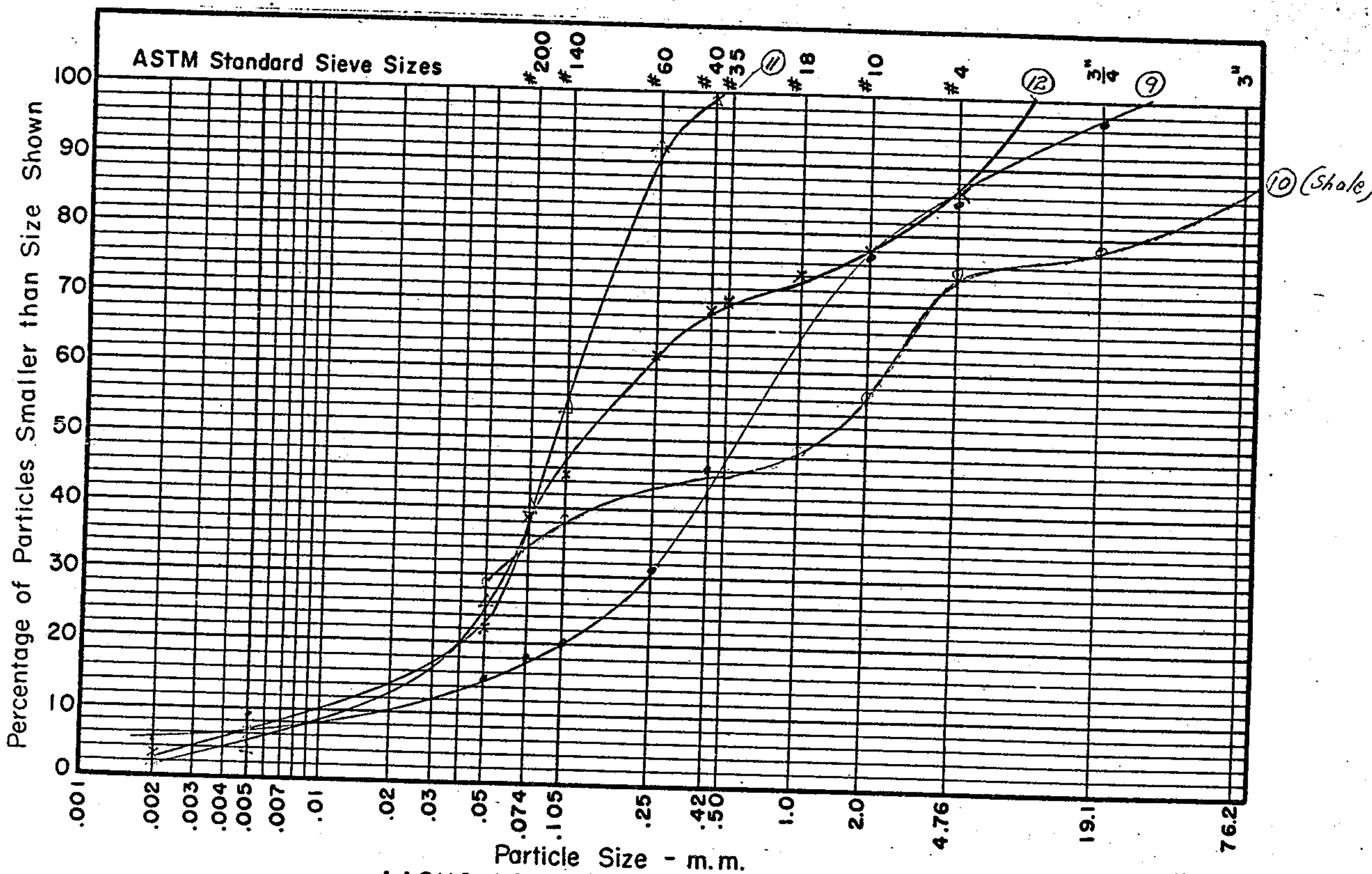




A.A.S.H.O.-A.S.T.M. SOIL SEPARATE CLASS

Clay	Silt	Sand		Gravel
-0.005	0.005 - 0.074	0.074-0.42	0.42-2.0	2.0 - 76.2

Fig. 2 – GRAIN SIZE ACCUMULATION CURVE



A.A.S.H.O.-A.S.T.M. SOIL SEPARATE CLASS

Clay	Silt	Sand		Gravel
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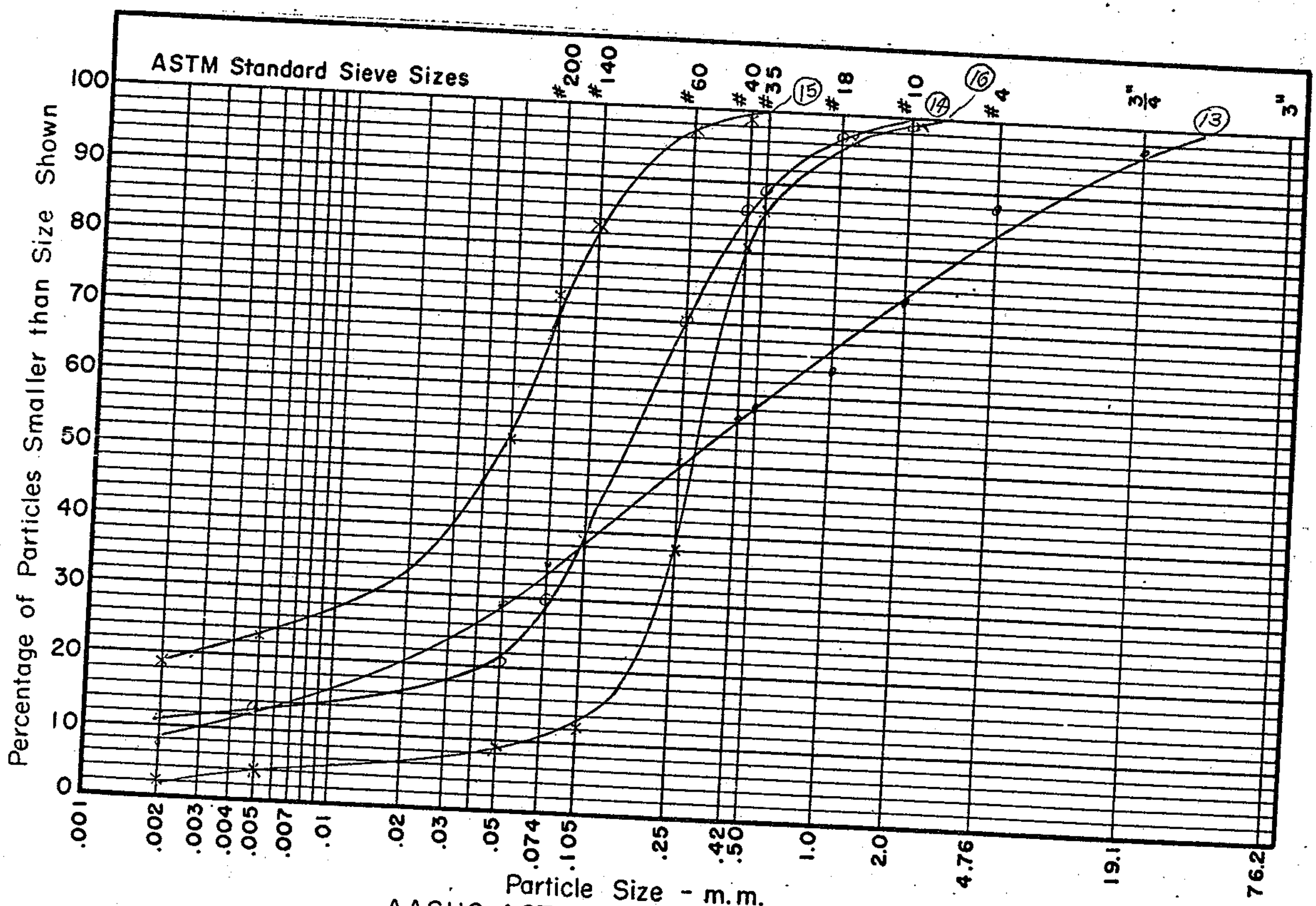
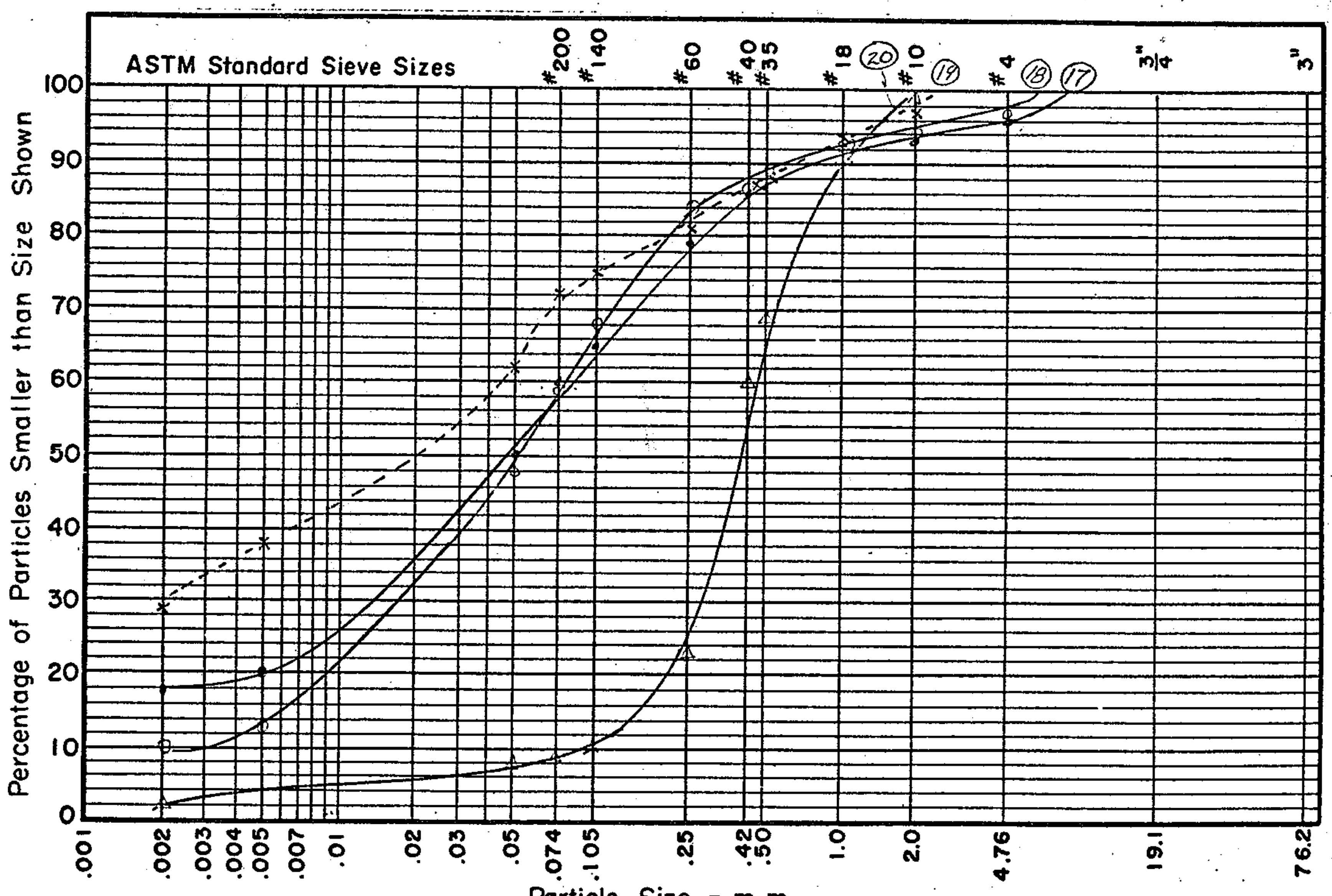
Fig. 3 – GRAIN SIZE ACCUMULATION CURVE



AASHO-ASTM. SOIL SEPARATE CLASS

Clay	Silt	Sand		Gravel
-0.005	0.005 - 0.074	0.074-0.42	0.42-2.0	2.0 - 76.2

Fig. 4 -GRAIN SIZE ACCUMULATION CURVE

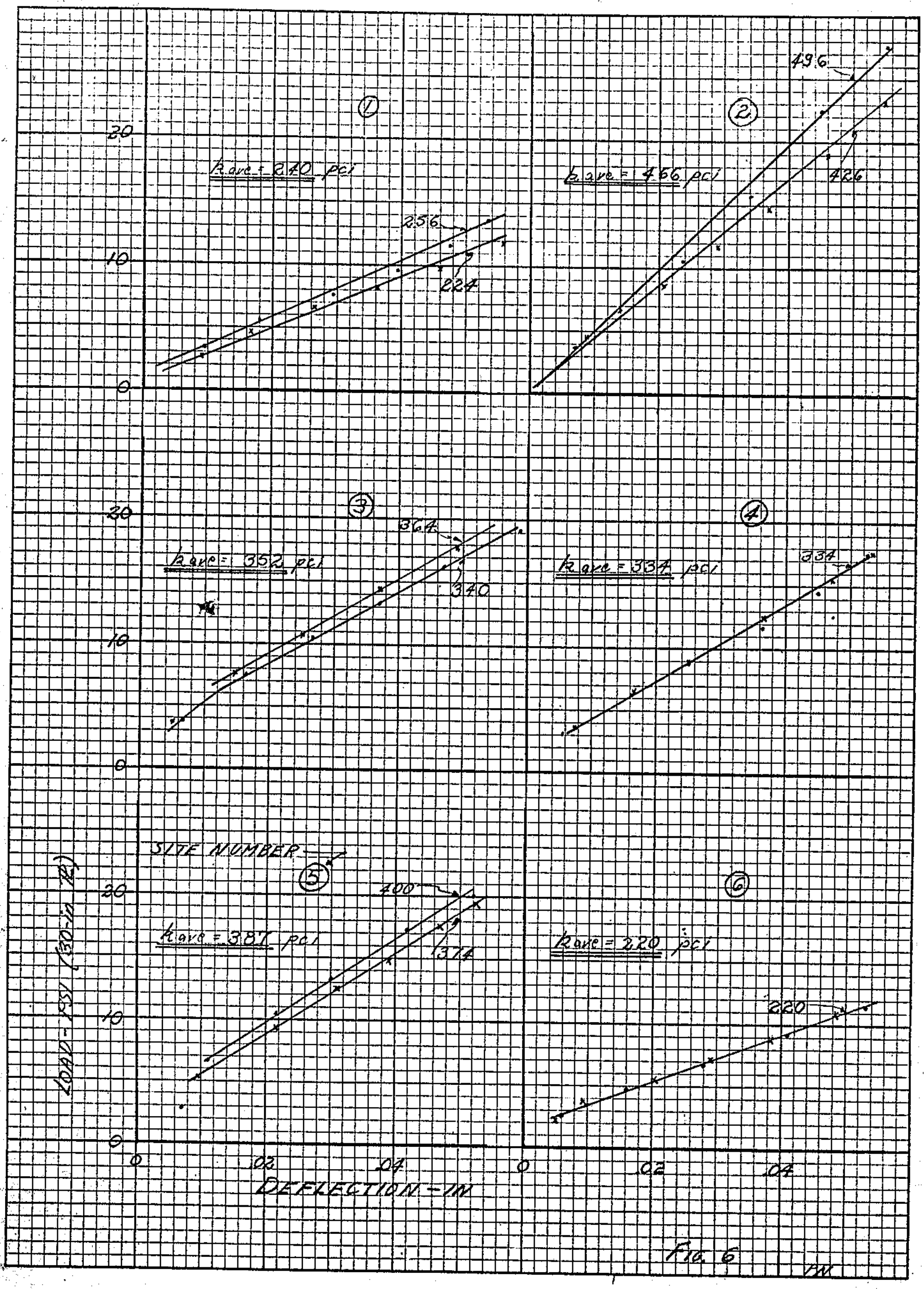


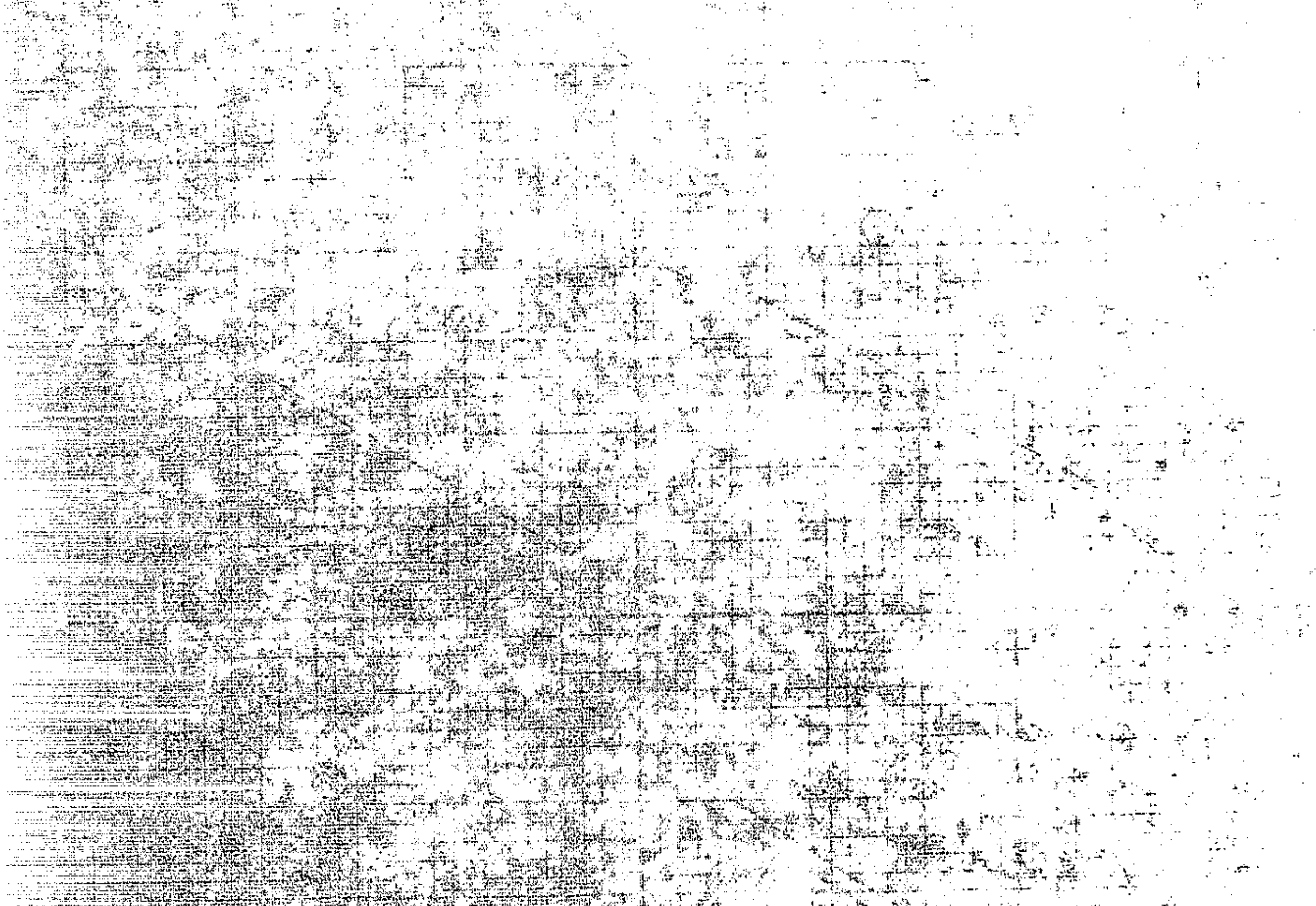
AASHO-ASTM. SOIL SEPARATE CLASS

Clay	Silt	Sand		Gravel
-0.005	0.005 - 0.074	0.074-0.42	0.42-2.0	2.0 - 76.2

Fig. 5 – GRAIN SIZE ACCUMULATION CURVE

CALIFORNIA -- PLATE BEARING TESTS





CALIFORNIA -- PLATE BEARING TESTS

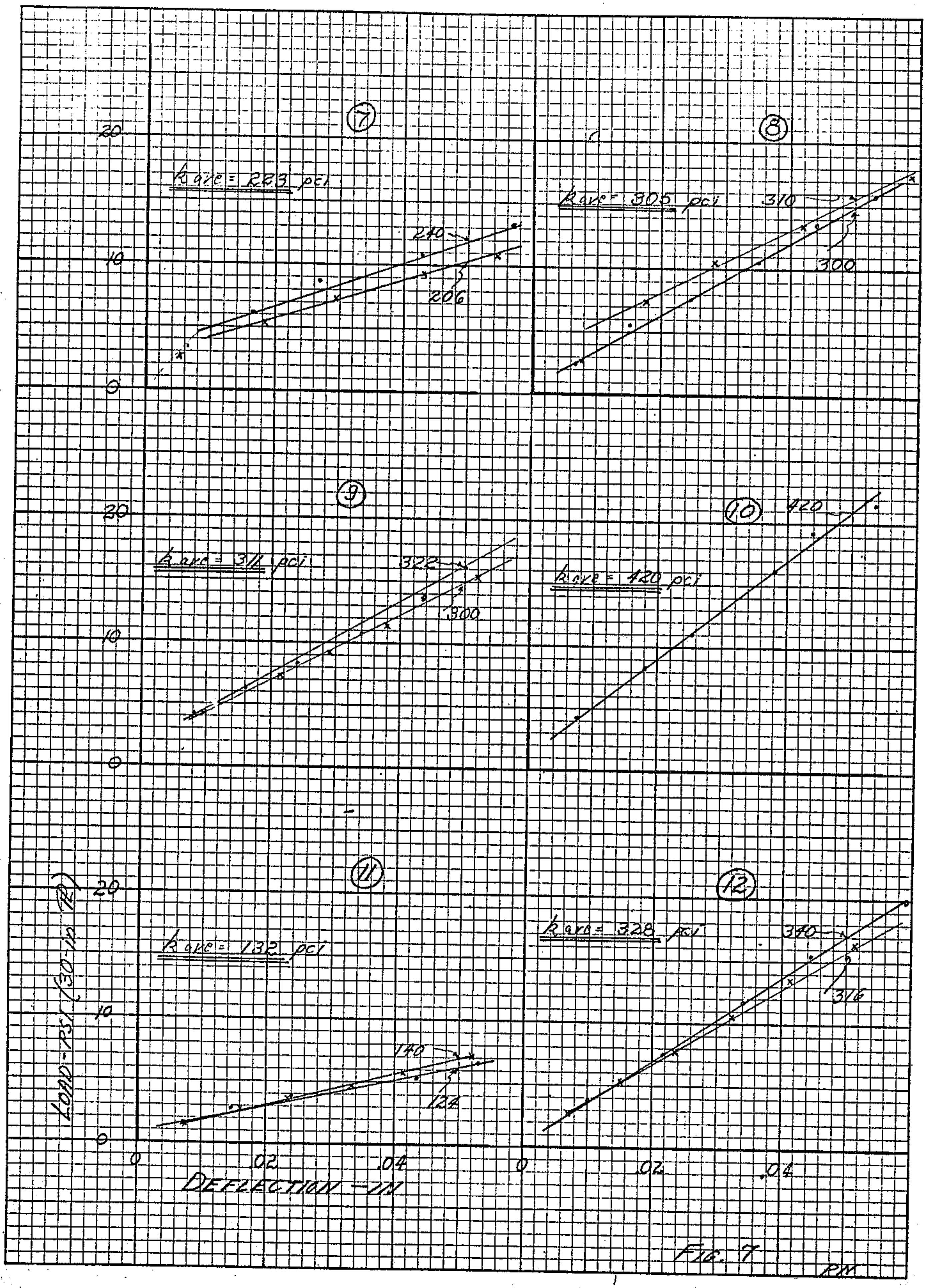
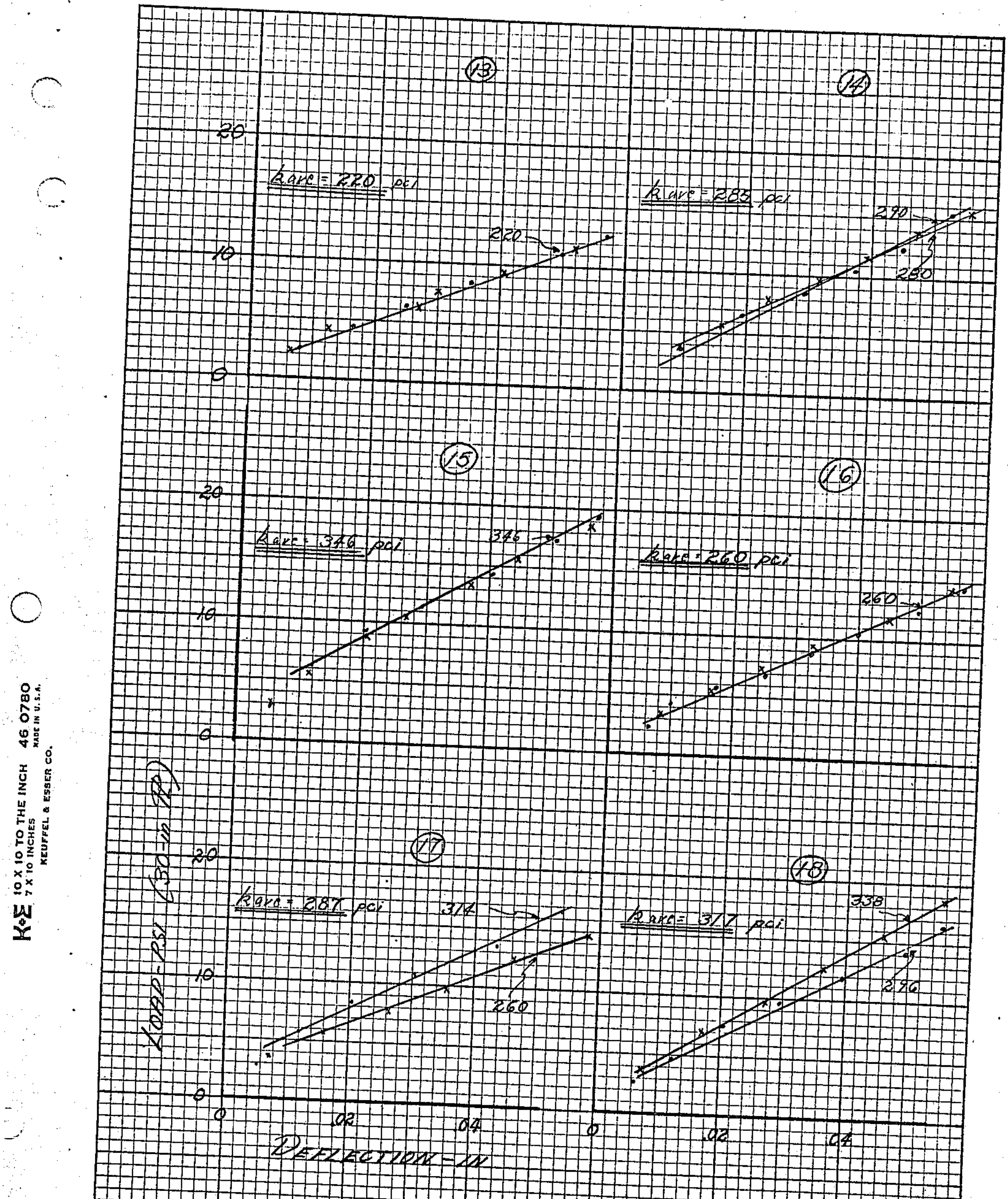


FIG. 7


13
k ave = 220 pci
220
20
10
0
14
k ave = 285 pci
290
280
15
k ave = 346 pci
346
16
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260
17
k ave = 287 pci
314
260
18
k ave = 317 pci
338
296
LOAD-PSI (30-in PL)
0
.02
.04
DEFLECTION-IN
10 X 10 TO THE INCH 46 0780
7 X 10 INCHES
KEUFFEL & ESSER CO.
MADE IN U.S.A.

Fig. 8

PW

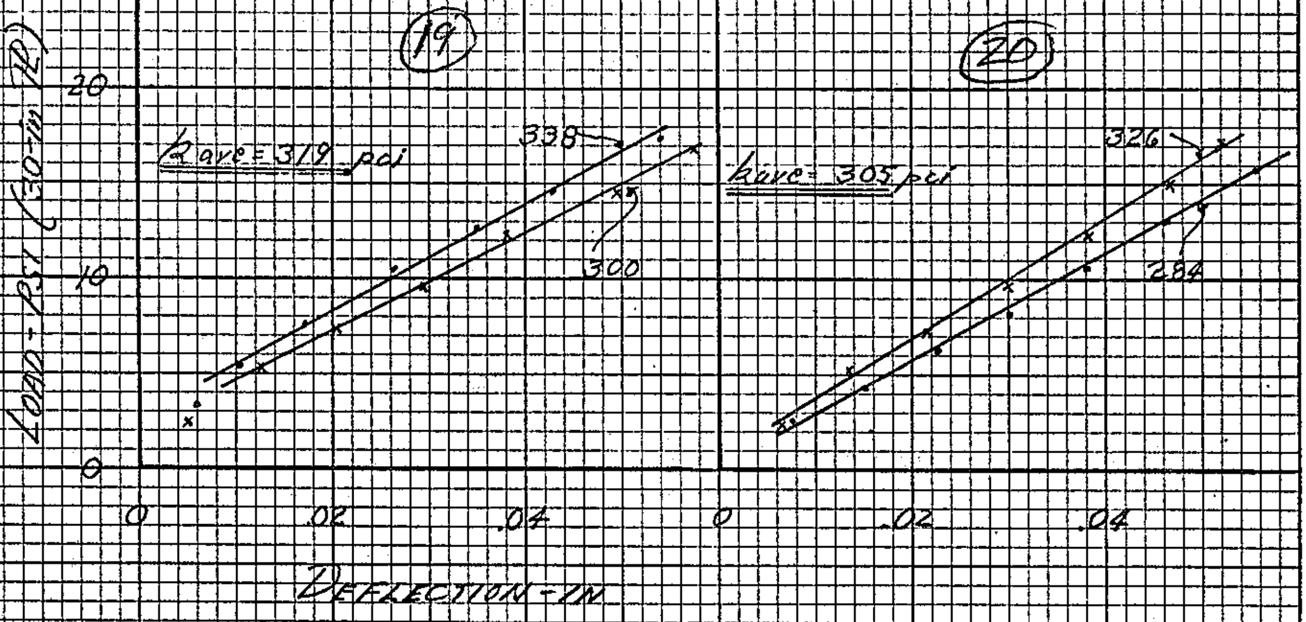
19
20
20
10
0
LOAD - PSI (30-in PL)
k ave = 319 pci
338
300
k ave = 305 pci
326
284
0
.02
.04
0
.02
.04
DEFLECTION - IN

FIG. 9

RN

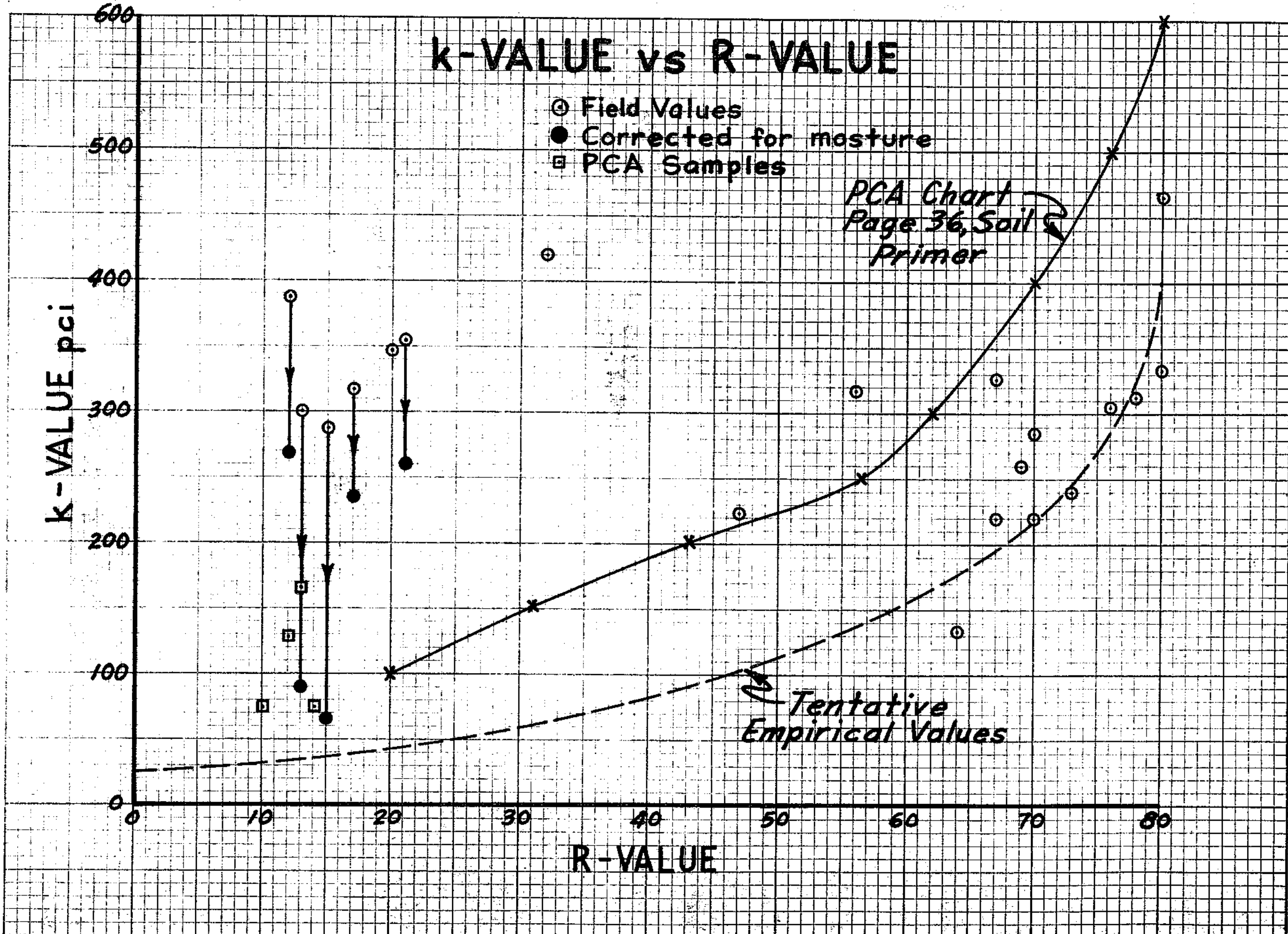

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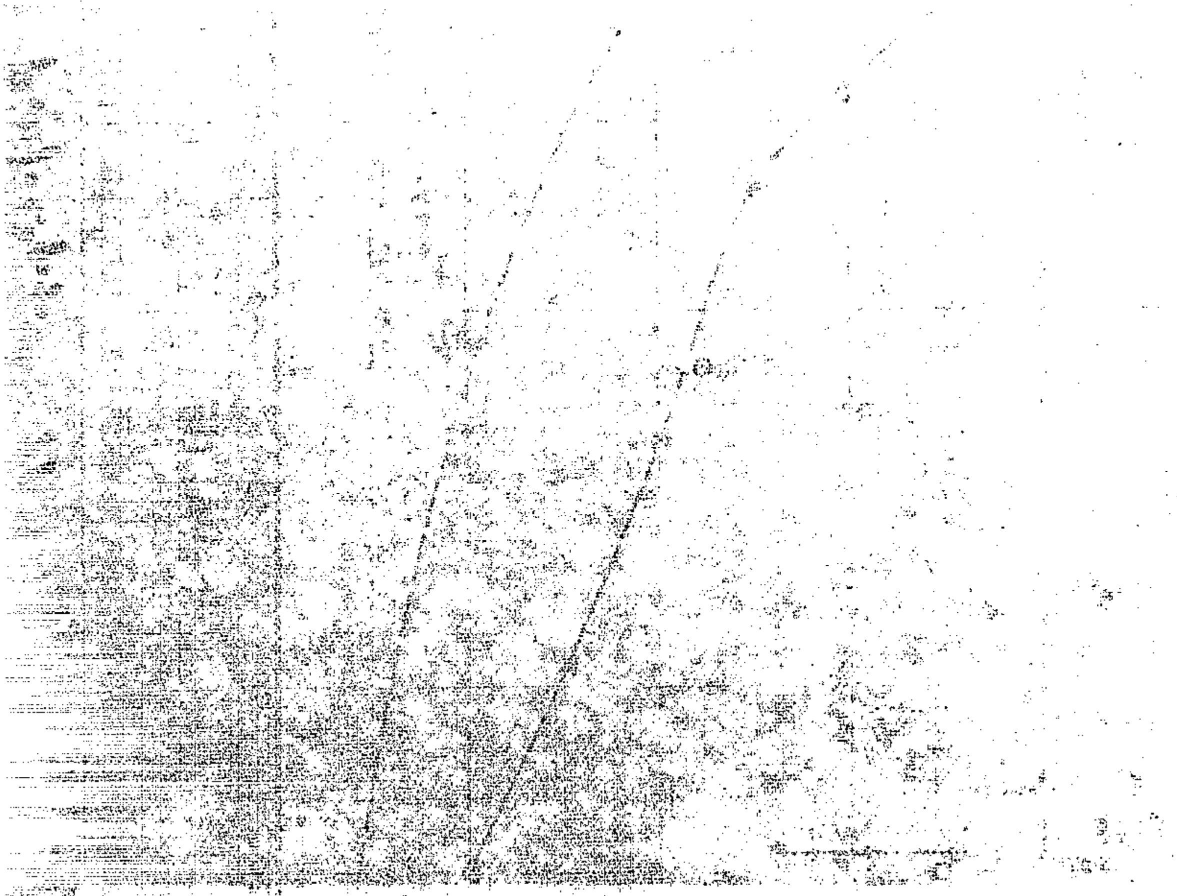
FIGURE 10



State of California

Memorandum

Transportation Agency

To : Mr. C. G. Beer
Urban Planning

Date: April 3, 1967

File : Research Project
HPR-1(3)(4),D-5-20
13-951010-30003
13-624130

From : Department of Public Works—Division of Highways
Headquarters Design Department

Subject:

Reference is made to the final report on the above-referenced project dated September 23, 1966, and titled "Report on Correlation Between R-Value and k-Value as a Basis for Concrete Pavement Design."

Subsequent to the submission of the final report, the Portland Cement Association performed consolidation tests on five of the original clay samples to obtain saturation correction factors and corrected k-values. These tests also were made in accordance with procedures of the U.S. Army Corps of Engineers. The differences were that standard size equipment was used and the samples were the original, sealed, in place specimens obtained when the plate bearing tests were made instead of recompacted samples.

The results of the new tests are tabulated as follows:

Site No.	Field Value k-pci	Saturation Correction Factor	Saturated Corrected k-pci
3	352	0.38	134
5	387	0.31	120
8	300	0.55	165
17	287	0.38	109
19	319	0.54	172

This data gives a closer grouping of the k-values as shown on the attached Figure 10 which has had these values added. Also shown is a "Minimum Value Curve" (heavy solid line) which has been used with an empirically adjusted adaptation of the latest Portland Cement Association method of concrete pavement design, HB35, 1966, titled "Thickness Design for Concrete Pavements."

A. C. ESTEP
Engineer of Design

Attach.

PIW:gl
cc Estep, Wagner

WH-38 Rev.